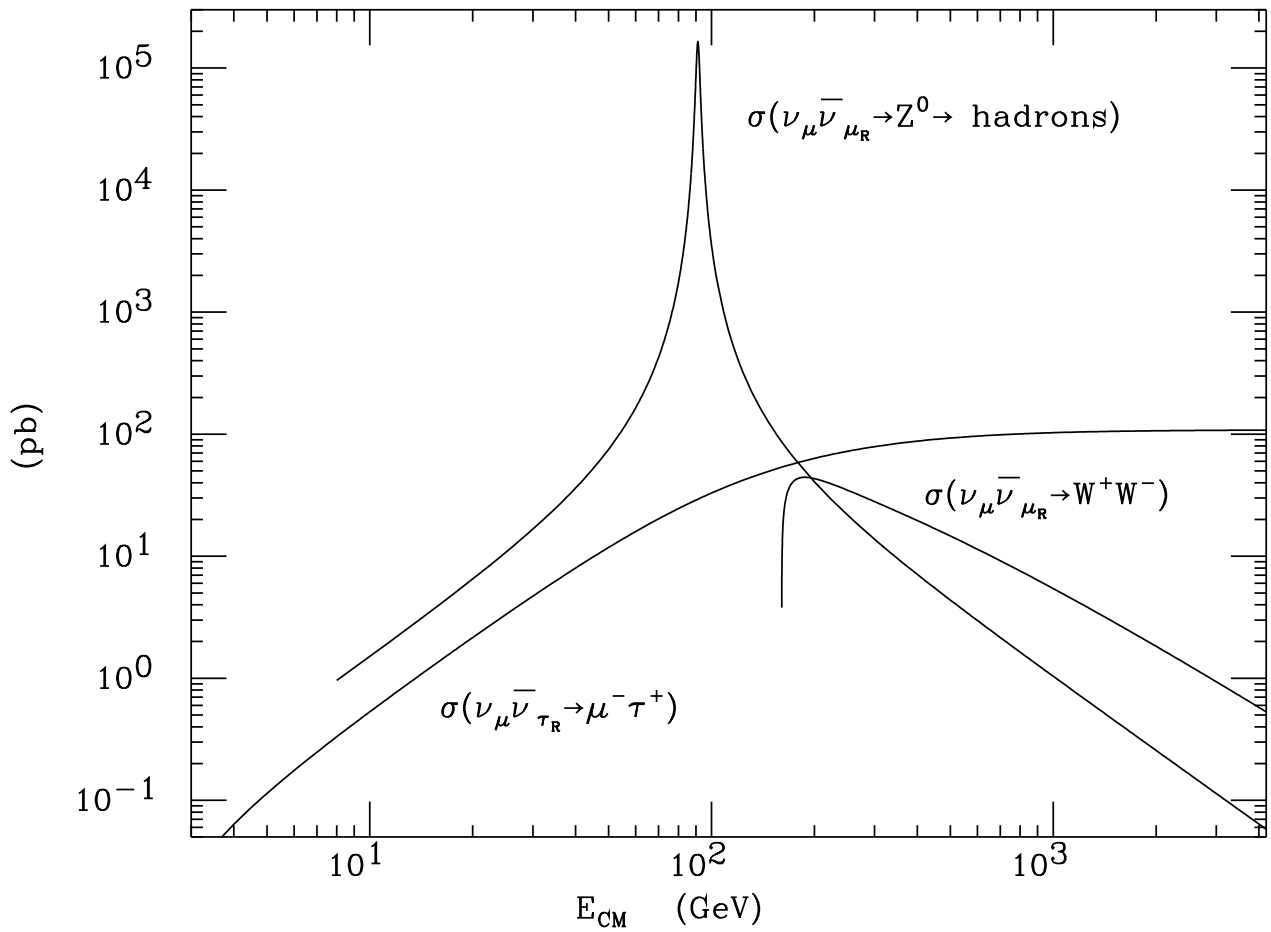
10^5
10^4
10^3
10^2
10^1
10^0
10^{-1}
(pb)
$\sigma(\nu_\mu\bar{\nu}_{\mu_R}\to Z^0\to$ hadrons)
$\sigma(\nu_\mu\bar{\nu}_{\mu_R}\to W^+W^-)$
$\sigma(\nu_\mu\bar{\nu}_{\tau_R}\to\mu^-\tau^+)$
10^1
10^2
10^3
E_{CM} (GeV)

TABLE 5

MAIN W^+W^- CHANNEL REACTIONS CHAINS FOR FINAL PROTON PRODUCTION

Reaction	Probability	Multiplicity	Secondary energy
1e)			
$p+\gamma \to (p,n)+8\pi$	$P_{1e} \simeq 1$	$M_{1e}=5$[a]	$E_\pi \sim \frac{E_p}{9}$
2e)			
$\pi^+ \to \mu^+ + \nu_\mu$ $\pi^- \to \mu^- + \bar{\nu}_\mu$	$P_{2e} \simeq 1$	$M_{2e}=1$	$E_\nu \sim 0.21 E_\pi = 2.3\cdot 10^{-2} E_p$
2e')			
$\mu^+ \to e^+ + \nu_e + \bar{\nu}_\mu$ $\mu^- \to e^- + \bar{\nu}_e + \nu_\mu$	$P_{2e'} \simeq 1$	$M_{2e'}=1$	$E_\nu \sim 0.26 E_\pi = 2.8\cdot 10^{-2} E_p$
3e)			
$\nu_\mu + \bar{\nu}_{\mu_r} \to W^+ + W^-$ $\bar{\nu}_\mu + \nu_{\mu_r} \to W^+ + W^-$	$P_{\nu\nu} = \sigma_{\nu_\mu \bar{\nu}_\mu} n_{\nu_r} l_g \sim 1.2\cdot 10^{-4\div -2}$	$M_{3e}=2$	$E_W \sim \frac{E_{\nu_\mu}}{2} = 1.1\cdot 10^{-2} E_p$
3e')			
$\nu_\mu + \bar{\nu}_{\mu_r} \to W^+ + W^-$ $\bar{\nu}_\mu + \nu_{\mu_r} \to W^+ + W^-$	$P_{\nu\nu} = \sigma_{\nu_\mu \bar{\nu}_\mu} n_{\nu_r} l_g \sim 10^{-4\div -2}$	$M_{3e'}=2$	$E_W \sim \frac{E_{\nu_\mu}}{2} = 1.4\cdot 10^{-2} E_p$
4e)			
$W^\pm \to p + X$	$P_{4e} \sim 0.7$	$M_{4e}=0.8$	$E_p \sim \frac{E_W}{33} = 3.5\cdot 10^{-4} E_p$
4e')			
$W^\pm \to p + X$	$P_{4e'} \sim 0.7$	$M_{4e'}=0.8$	$E_p \sim \frac{E_W}{33} = 4.3\cdot 10^{-4} E_p$
finally: eq.(1e)	$^{e}P_{tot}^{WW} = \Pi_i M_i P_i \sim 6.6\cdot 10^{-4\div -2}$ $^{e'}P_{tot}^{WW} = \Pi_i M_i P_i \sim 5.6\cdot 10^{-4\div -2}$		$E_p^{WW} \sim 7.3\cdot 10^{23}\ eV$

Additional reactions not included in the present analysis:

W^+W^- channels if there is neutrino flavor mixing $\nu_\mu \leftrightarrow \nu_\tau$

3'e)

$\bar{\nu}_\tau + \nu_{\tau_r} \to W^+ + W^-$
$\nu_\tau + \bar{\nu}_{\tau_r} \to W^+ + W^-$

W^+W^- channel whose efficiency is however suppressed by lower $\nu_e, \bar{\nu}_e$ energies and $n_{\nu_e}, n_{\bar{\nu}_e}$ densities

3"e)

$\bar{\nu}_e + \nu_{e_r} \to W^+ + W^-$

[a] This multiplicity refers only to charged pions

[b] In calculating the probability for the $\nu\nu$ interaction we assumed: $n_{\nu_r} = 10^{7\div 9}\ cm^{-3}$, $l_g \sim 10^{24}\ cm$. The $\sigma_{\nu_\mu \bar{\nu}_\tau}$ value has been obtained from the corresponding cross section and center of mass energy in fig.1